Designing Safe Lifting Tasks for Occupational Workers

A Synopsis

Submitted for the partial fulfillment of the requirements for the

Degree of

Doctor of Philosophy

in

Mechanical Engineering

Submitted by

Ravi Bansal

Prof. Sanjay K Srivastava
Supervisor
Department of Mechanical Engineering

Prof. V. Prem Pyara
Dean
Faculty of Engineering
Engineering

Prof. S. K. Gaur
Head
Department of Mechanical

DEPARTMENT OF MECHANICAL ENGINEERING
FACULTY OF ENGINEERING
DAYALBAGH EDUCATIONAL INSTITUTE
DAYALBAGH, AGRA 282110

DESIGNING SAFE LIFTING TASKS FOR OCCUPATIONAL WORKERS

Low back pain is a disorder that commonly affects the occupational workers, resulting in disability, and a socioeconomic burden. Occupational repetitive and/or heavy lifting is a known risk factor for the development of low back pain (Wai et al., 2010). Statistics from around the world shows that nearly one-quarter of the working population falls victim to manual handling injuries especially low back injuries (Kothiyal and Kayis, 2000; Graham et al., 2009). Manual lifting is the highest classified cause (19.6%) of mishap incidence and also the highest classified cause (31.1%) of injury on the job as per the Kansas department of human resources (2000). It is cited that the second greatest reason for lost workdays is injuries due to overexertion when performing lifting tasks (Snook, 1988). It is estimated that 2% of the U. S. workplace suffers compensable back injuries for a total of over 500,000 injuries annually, and that low back cases constitute about 16% of all workers compensation cases and are responsible for 33% of the total cost (Andersson, 1998; Bernard, 1997). Researchers from diverse fields have focused manual material-handling (MMH) tasks to reduce manual handling injuries which led to the development of guidelines such as National Institute for Occupational Safety and Health (NIOSH) work practices guide and lifting equations (NIOSH, 1981; Waters et al., 1993), National Occupational Health and Safety Commission (NOHSC) manual handling Standard (NOHSC, 1990), design database (Tables of recommended weight of lifting) for lifting (Mital et al., 1993), etc. The primary motivation for these research efforts has been to model human capabilities so that the demands of MMH tasks can be designed at or below

the worker capacity to perform the task. Various criteria for defining acceptable task demands have been developed from the principles of biomechanics, physiology, and psychophysics (Ayoub and Mital, 1989; Dempsey, 1998). Based upon these criteria and researches, NIOSH equation has assisted ergonomists and occupational safety and health practitioners in analyzing the lifting demands on the low back. Since NIOSH equation could only be applied to symmetrical lifting tasks that do not involve torso twisting, the equation was revised and expanded in 1991 for application to a greater variety of lifting tasks (Waters et al., 1993). MMH, in general, involves lifting, pushing, pulling, lowering, holding and carrying of loads, however, we primarily focus on lifting activities in the proposed research work.

It is commonly agreed that the cause of lower back pain and injury is frequently related to the posture of lifting, the load, muscle fatigue etc. Many investigations (Norman et al., 1998) have demonstrated that there is a clear relationship between low back injuries and biomechanical factors such as posture at the initiation of the lift (trunk inclination and knee angles), moment, shear, and compression forces at muscle/joint complexes, trunk sagittal angle (flexion), peak trunk velocity, bending frequency, and average force on the hands.

Lifting involves the various human joints in a complex manner. The external force applied by the load to be lifted is shared primarily by the low back, hip and knee joints. The relative proportions of their sharing is also influenced by human factors (age, sex, body dimensions, strength of various involved muscles etc.), task factors (load, posture

awkwardness, location of load, lift frequency, speed of lifting, size of container, coupling etc.), and environmental factors (temperature, humidity, ventilation, noise etc). Kumar (1984) suggested that posture during lifting is a crucial factor. It is perhaps due to this reason, that training on manual handling tasks in industry emphasizes the role of 'correct' postures which should be adopted by workers during lifting the objects (NIOSH, 1981). Studies have been carried out to determine, using physiological and psychophysical methods, safe and perhaps optimal lifting techniques / postures. Parnianpour et al. (1987) have pointed out the fallacy of a single correct lifting technique. They recommend different lifting techniques for individuals with different joint problems. Kumar (1984) has examined three different lifting postures (stoop lifting, squat lifting and 'free style' lifting with no postural constraints) to determine which of these is/are optimal. From the subjective point of view, squat lifting was found to be more tiring than straight leg posture. In terms of physiological cost, the stoop method (bent back, straight legs) of lifting was found to be least and the squat method (flexed knee, straight back) most demanding. Subjectively free style lifting was considered the best.

Lifting postures are as much a function of individual characteristics as of external constraints. To clarify the role of various factors such as magnitude of load, individual anthropometric characteristics, shape, size and location of loads etc. in determining the optimal working postures, a model approach can be reasonable, economic and less time consuming. NIOSH believes that the revised equation is more likely to protect most workers than the 1981 equation, though differences in the physique of varying racial populations limiting the applicability of this equation have not been considered.

Most MMH-related studies have been based in Europe and North America and the data were obtained from the Caucasian population (Maiti, 2008). On the contrary the manual material-handling problem is more severe in developing and underdeveloped countries and research on the populations of these countries is needed (Wu, 2003). In Indian context, the laborers are continuously over-exhausted without the protection of any constraint law. These workers are employed temporarily by the labor contractors on daily wage basis, not as the direct payee of the organization. No records are maintained on their health or industrial accidents. The Factory Act, 1948, does not indicate the safe load limit for Indian population. According to Joshi et al. (2001), the existing Indian Factory rule inadvertently created the occupational health hazard conditions in industries. In the proposed research work, we intend to develop a system to investigate and clarify the role of various factors involved in the load lifting for occupational workers in and around Agra. A model with multi-segment link may be devised for determining the joint moments and reactive forces during load lifting. The model can then be used to search for optimal values of factors for reducing work related disorders. We can also determine postural angles based on reducing the reaction force/moment at the low back subject to all other muscle-joint complexes not being overstressed.

Another important dimension of research in lifting tasks is determining maximum acceptable weight limit (MAWL) by the workers (Maiti and Ray, 2004). MAWL is the highest acceptable workload, which can be lifted comfortably based on their perceived exhaustion level (Gamberale, 1985). Use of psychophysical method in determining

MAWL in repetitive lifting jobs is well established (Snook, 1978; Legg and Myles, 1981). Many authors (Legg and Myles, 1981; Mital and Manivasagan, 1983; Aghazadeh and Ayoub, 1985; Karwowski and Yates, 1986; Ciriello et al., 1990; Fernandez et al., 1991) suggested that the psychophysical approach is a reliable method in assessing the perceived exertion during MMH task in low and moderate frequencies ($\leqslant$4 lifts min^{-1}). However, it is also reported that this method overestimates the workers' capacity for high lifting frequency (>6 lifts min^{-1}) conditions (Ciriello and Snook, 1983; Asfour et al., 1985; Karwowski and Yates, 1986). Regarding the selection of the duration of simulated experiment which should reflect the 8 hour job criteria in industry, Ciriello et al. (1990) suggested that 40 min work is sufficient to select the acceptable load. Ayoub and Mital (1989) categorically mentioned that 40–45 min work period is sufficient to determine the weight, which the subject can lift for 12 hour duration even if it includes 4 hour overtime about which they have no prior warning. In psychophysical experiment, the task is generally initialized with a random load weight and the subject is asked to adjust the load based on their choice such that the load will be acceptable for 8 h for repetitive handling operation. Snook (1978) provided a 40 min adjustment period to allow the participants to monitor their own feelings and adjust the load weight. A significant difference of this adjustment period is found in earlier studies. Some authors (Garg and Saxena, 1982; Garg and Beller, 1994) used a longer adjustment period (i.e. 45, 50, or 60 min). Again, in other studies (Mital, 1984 and Mital and Manivasagan, 1983; Karwowski and Yates, 1986; Mital and Aghazadeh, 1987; Zhu and Zhang, 1990; Chen et al., 1992), it is mentioned that participants could determine the MAWL load weight within shorter adjustment period. In these studies, the authors identified many factors affecting this perceived

subjective response such as, workers and load characteristics, type of task, work environment etc. and also the load weight factor. As part of this research work it is proposed to investigate the estimation of maximum acceptable load limit for manual lifting for occupational workers near Agra such as footwear production, brick manufacturing etc. The possible investigations can be (1) to estimate the MAWL level for brick/shoe/other workers following physiological / psychophysical criteria, (2) to study the psychophysical rating responses in different occupations against lifted load, (3) to find the effect of task factors on physiological parameters.

Most of the research efforts in manual lifting include only symmetric lifting; asymmetric lifting activities have been studied rarely. It is generally believed that asymmetric lifting involving torso twisting is more harmful to the back and spine than symmetric lifting. Although practically all manual handling training programmers recommend that asymmetric lifting should be avoided whenever possible (Rodgers, 1985), workers twisting their torsos while lifting is still inevitable in some work situations, especially during loading and unloading in restricted workplaces or for irregular material handling. A few studies on asymmetric lifting have been conducted (Mital and Manivasagan, 1983; Mital and Fard, 1986; Garg and Badger, 1986; Garg and Banaag, 1988; Rodrigues et al., 1989; Chen et al., 1992; Mital, 1992; Wu, 2000; Maiti 2008). More recently a study compared range of motion of trunk and pelvis during an asymmetric lifting task of a box between a group with a history of low back pain and a group with no history of low back pain (Seay et al., 2013). It also detailed out the implications for studying lifting paradigms at sub-maximal effort over longer periods of time. Most of these studies have

occurred in Europe and North America and the data were obtained from Caucasian populations. Therefore we intend to develop a system to facilitate the investigations of (1) the effects of angle of asymmetry on the low back pain, and (2) the resulting physiological costs and rating of perceived exertion for asymmetric lifting tasks by occupational workers near Agra.

It is important to educate the workers about the effects of various lifting parameters on the trunk and the upper extremity muscle recruitment to control the mechanical load on the muscles and spine. We propose to assess the effects on the upper extremity muscle recruitment when controlling the different lifting parameters such as horizontal distance of load, vertical distance of load, lifting frequency, lifting weight etc using electromyography signals of trunk and upper extremity muscles. The effects of heavier and repetitive lifting on change in the muscle recruitment throughout the lifting period can be investigated.

REFERNCES

Aghazadeh, F. and Ayoub, M. M., 1985. A comparison of dynamic and static-strength models for prediction of lifting capacity, *Ergonomics* 28, pp. 1409–1417.

Andersson, G. B. J., 1998. Epidemiology of low back pain. *Acta Orthopaedica Scandinavica* 69 (S281), pp. 28-31.

Asfour, S. S., Ayoub, M. M. and Mital, A., 1985. Computer models for energy cost prediction of manual lifting and lowering, *Computers and Industrial Engineering* 9, pp. 376–379.

Ayoub, M. M. and Mital, A., 1989. *Manual Materials Handling*, Taylor & Francis, London.

Bernard, B. P., Ed. 1997. *Musculoskeletal disorders and workplace factors: A critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and lower back*. U. S. Department of Health and Human Services.

Chen, F., Aghazadeh, F. and Lee, K. S., 1992. Prediction of the maximum acceptable weight of symmetrical and asymmetrical lift using direct estimation method. *Ergonomics* 35, pp. 755–768.

Ciriello, V. M. and Snook, S. H. 1983. A study of size, distance, height and frequency effects on manual handling tasks. *Human Factors* 25, pp. 473–483.

Ciriello, V. M., Snook, S. H., Blick, A.C. and Wilkinson, P. L., 1990. The effects duration on psychophysically determined maximum acceptable weights and forces. *Ergonomics* 33, pp. 187–200.

Dempsey, P. G., 1998. A critical review of biomechanical, epidemiological, physiological and psychophysical criteria for designing manual materials handling tasks. *Ergonomics* 41, pp. 73–88.

Fernandez, J. E., Ayoub, M. M. and Smith, J. L., 1991. Psychophysical lifting capacity over extended periods. *Ergonomics* 34, pp. 23–32.

Gamberale, F., 1985. The perception of exertion. *Ergonomics* 28, pp. 299–308.

Garg, A. and Beller, D., 1994. A comparison of isokinetic lifting strength with static strength and maximum acceptable weight with special reference to speed of lifting. *Ergonomics* 37, pp. 1363–1374.

Garg, A. and Saxena, U., 1982. Maximum frequency acceptable to female workers for one-hand lifts in the horizontal plane. *Ergonomics* 25, pp. 839–853.

Garg, A. and Badger, D., 1986. Maximum acceptable weights and maximum voluntary isometric strengths for asymmetric lifting. *Ergonomics* 29, pp. 879–892.

Garg, A. and Banaag, J., 1988. Maximum acceptable weights, heart rates and RPEs for one hour's repetitive asymmetric lifting. *Ergonomics* 31, pp. 77–96.

Graham, R. B., Michael, J. A., and Stevenson, J. M., 2009. Effectiveness of an on-body lifting aid at reducing low back physical demands during an automotive assembly task: Assessment of EMG response and user acceptability. *Applied Ergonomics* 40(5), pp. 936-942.

Joshi, T. K., Menon, K. K. and Kishore, J., 2001. Musculoskeletal disorders in industrial workers of Delhi. *International Journal of Occupational and Environmental Health* 7, pp. 217–221.

Kansas Department of Human Resources. 2000. *Workers Compensation 26th Annual report*. Fiscal Year 2000.

Karwowski, W. and Yates, J. W., 1986. Reliability of the psychophysical approach to manual lifting of liquids by females. *Ergonomics 29*, pp. 237–248.

Kothiyal, K. P. and Kayis, A. B., 2001. Workplace layout for seated manual handling tasks: an electromyography study. *International Journal of Industrial Ergonomics* 27, pp. 19-32.

Kumar, S., 1984. The physiological cost of three different methods of lifting in sagittal and lateral planes. *Ergonomics* 27, pp. 425–433.

Legg, S. J and Myles, W. S., 1981. Maximum acceptable repetitive lifting workload for an 8 hour work-day using psychophysical and subjective rating methods. *Ergonomics* 24, pp. 907–916.

Maiti, R., 2008. Workload assessment in building construction related activities in India. *Applied Ergonomics* 39, pp. 754-765.

Mital, A. and Aghazadeh, F., 1987. Psychophysical lifting capabilities for overreach heights. *Ergonomics* 30, pp. 901–909.

Mital, A., and Manivasagan, I., 1983. Subjective estimates of one handed carrying tasks. *Applied Ergonomics* 14, pp. 265–269.

Mital, A., 1984. Maximum weights of lift acceptable to male and female industrial workers for extended work shifts. *Ergonomics* 27, pp. 1115–1126.

Mital, A. and Fard, H. F., 1986. Psychophysical and physiological responses to lifting symmetrical and asymmetrical loads symmetrically and asymmetrically. *Ergonomics* 29, pp. 1263–1272.

Mital, A., Nicholson, A. S. and Ayoub, M. M., 1993. *A Guide to Manual Materials Handling*. Taylor and Francis, London, UK.

NIOSH (National Institute of Occupational Safety and Health), 1981. *Work practices guide for manual lifting*. DHHS (NIOSH) Publication No. 81-122, Cincinnati, OH.

NOHSC, 1990. *National Standard on Manual Handling* (NOHSC:1001). Australian Government Publications Service, Canberra, ACT, Australia.

Norman, R., Wells, R., Neumann, P., Frank, J., Shannon, H., Kerr, M. and the Ontario Universities Back Pain Study Group 1998. A comparison of peak vs. cumulative physical work exposure risk factors for the reporting of low back pain in the automotive industry. *Clinical Biomechanics* 13**,** pp. 561-573.

Parnianpour, M., Bejjani, F. and Pavlidis, L., 1987. Worker training: The fallacy of a single, correct lifting technique. *Ergonomics* 30, pp. 331-334.

Pham, D. T. and Onder, H. H., 1992. A knowledge-based system for optimizing workplace layouts using a genetic algorithm. *Ergonomics* 35(12), pp. 1479–1487.

Rodrigues, C. C., Congleton, J. J., Koppa, R. J. and Huchingson, R. D., 1989. Maximum acceptable weight of lift for an asymmetrical combination manual handling task. *International Journal of Industrial Ergonomics* 4, pp. 245–253.

Seay, J. F., Sauer, S. G., Frykman, P. N. and Roy, T. J., 2013. A history of low back pain affects pelvis and trunk mechanics during a sustained lift/lower task. *Ergonomics* 56(6), pp. 944-953, DOI:10.1080/00140139.2013.781234

Sebald, A. V. and Fogel, L. J., 1994. Editors, *Proceedings of the 3rd Conference on Evolutionary Computation*, World Scientific, New Jersey pp. 371.

Snook, S. H., 1978. The design of manual handling tasks. *Ergonomics* 21(7), pp. 963-985.

Snook, H., 1988. Approaches to the control of back pain in industry: Job design, Job placement and Education/ training. *Professional Safety* 33(8), pp. 23-31.

Wai, E. K., Roffey, D. M., Bishop, P., Kwon, B. K. and Dagenais, S., 2010. Causal assessment of occupational lifting and low back pain: results of a systematic review. *The Spine Journal* 10(6), pp. 554-566.

Waters, P. R., Putz-Anderson, V., Garg, A. and Fine, L., 1993. Revised NIOSH equation for the design and evaluation of manual lifting tasks. *Ergonomics* 36(7), pp. 749–776.

Wu, S. P., 2003. Maximum acceptable weights for asymmetric lifting of Chinese females. *Applied Ergonomics* 34, pp. 215–224.

Wu, S. P., 2000. Psychophysically determined symmetric and asymmetric lifting capacity of Chinese males for one hour's work shifts. *International Journal of Industrial Ergonomics* 25, pp. 675–682.

Zhu, Z. and Zhang, Z., 1990. Maximum acceptable repetitive lifting workload by Chinese subjects. *Ergonomics* 33, pp. 875–884.